ing evolutionary contest, with the death of one contestant the price of defeat, and with natural selection playing the role of umpire. Now let's consider the form of the contest: blitzkrieg or guerrilla war?

SUPPOSE THAT ONE counts the number of cases of some particular infectious disease in some geographic area, and watches how the numbers change with time. The resulting patterns differ greatly among diseases. For certain diseases, like malaria or hookworm, new cases appear any month of any year in an affected area. So-called epidemic diseases, though, produce no cases for a long time, then a whole wave of cases, then no more cases again for a while.

Among such epidemic diseases, influenza is one personally familiar to most Americans, certain years being particularly bad years for us (but great years for the influenza virus). Cholera epidemics come at longer intervals, the 1991 Peruvian epidemic being the first one to reach the New World during the 20th century. Although today's influenza and cholera epidemics make front-page stories, epidemics used to be far more terrifying before the rise of modern medicine. The greatest single epidemic in human history was the one of influenza that killed 21 million people at the end of the First World War. The Black Death (bubonic plague) killed one-quarter of Europe's population between 1346 and 1352, with death tolls ranging up to 70 percent in some cities. When the Canadian Pacific Railroad was being built through Saskatchewan in the early 1880s, that province's Native Americans, who had previously had little exposure to whites and their germs, died of tuberculosis at the incredible rate of 9 percent per year.

The infectious diseases that visit us as epidemics, rather than as a steady trickle of cases, share several characteristics. First, they spread quickly and efficiently from an infected person to nearby healthy people, with the result that the whole population gets exposed within a short time. Second, they're "acute" illnesses: within a short time, you either die or recover completely. Third, the fortunate ones of us who do recover develop antibodies that leave us immune against a recurrence of the disease for a long time, possibly for the rest of our life. Finally, these diseases tend to be restricted to humans; the microbes causing them tend not to live in the soil or in other animals. All four of these traits apply to what Americans think

of as the familiar acute epidemic diseases of childhood, including measles, rubella, mumps, pertussis, and smallpox.

The reason why the combination of those four traits tends to make a disease run in epidemics is easy to understand. In simplified form, here's what happens. The rapid spread of microbes, and the rapid course of symptoms, mean that everybody in a local human population is quickly infected and soon thereafter is either dead or else recovered and immune. No one is left alive who could still be infected. But since the microbe can't survive except in the bodies of living people, the disease dies out, until a new crop of babies reaches the susceptible age—and until an infectious person arrives from the outside to start a new epidemic.

A classic illustration of how such diseases occur as epidemics is the history of measles on the isolated Atlantic islands called the Faeroes. A severe epidemic of measles reached the Faeroes in 1781 and then died out, leaving the islands measles free until an infected carpenter arrived on a ship from Denmark in 1846. Within three months, almost the whole Faeroes population (7,782 people) had gotten measles and then either died or recovered, leaving the measles virus to disappear once again until the next epidemic. Studies show that measles is likely to die out in any human population numbering fewer than half a million people. Only in larger populations can the disease shift from one local area to another, thereby persisting until enough babies have been born in the originally infected area that measles can return there.

What's true for measles in the Faeroes is true of our other familiar acute infectious diseases throughout the world. To sustain themselves, they need a human population that is sufficiently numerous, and sufficiently densely packed, that a numerous new crop of susceptible children is available for infection by the time the disease would otherwise be waning. Hence measles and similar diseases are also known as crowd diseases.

OBVIOUSLY, CROWD DISEASES could not sustain themselves in small bands of hunter-gatherers and slash-and-burn farmers. As tragic modern experience with Amazonian Indians and Pacific Islanders confirms, almost an entire tribelet may be wiped out by an epidemic brought by an outside visitor—because no one in the tribelet had any antibodies against the microbe. For example, in the winter of 1902 a dysentery epidemic brought

by a sailor on the whaling ship *Active* killed 51 out of the 56 Sadlermiut Eskimos, a very isolated band of people living on Southampton Island in the Canadian Arctic. In addition, measles and some of our other "childhood" diseases are more likely to kill infected adults than children, and all adults in the tribelet are susceptible. (In contrast, modern Americans rarely contract measles as adults, because most of them get either measles or the vaccine against it as children.) Having killed most of the tribelet, the epidemic then disappears. The small population size of tribelets explains not only why they can't sustain epidemics introduced from the outside, but also why they never could evolve epidemic diseases of their own to give back to visitors.

That's not to say, though, that small human populations are free from all infectious diseases. They do have infections, but only of certain types. Some are caused by microbes capable of maintaining themselves in animals or in the soil, with the result that the disease doesn't die out but remains constantly available to infect people. For example, the yellow fever virus is carried by African wild monkeys, whence it can always infect rural human populations of Africa, whence it was carried by the transatlantic slave trade to infect New World monkeys and people.

Still other infections of small human populations are chronic diseases such as leprosy and yaws. Since the disease may take a very long time to kill its victim, the victim remains alive as a reservoir of microbes to infect other members of the tribelet. For instance, the Karimui Basim of the New Guinea highlands, where I worked in the 1960s, was occupied by an isolated population of a few thousand people, suffering from the world's highest incidence of leprosy—about 40 percent! Finally, small human populations are also susceptible to nonfatal infections against which we don't develop immunity, with the result that the same person can become reinfected after recovering. That happens with hookworm and many other parasites.

All these types of diseases, characteristic of small isolated populations, must be the oldest diseases of humanity. They were the ones we could evolve and sustain through the early millions of years of our evolutionary history, when the total human population was tiny and fragmented. These diseases are also shared with, or similar to the diseases of, our closest wild relatives, the African great apes. In contrast, the crowd diseases, which we discussed earlier, could have arisen only with the buildup of large, dense human populations. That buildup began with the rise of agriculture starting about 10,000 years ago and then accelerated with the rise of cities starting several thousand years ago. In fact, the first attested dates for many familiar infectious diseases are surprisingly recent: around 1600 B.C. for smallpox (as deduced from pockmarks on an Egyptian mummy), 400 B.C. for mumps, 200 B.C. for leprosy, A.D. 1840 for epidemic polio, and 1959 for AIDS.

WHY DID THE rise of agriculture launch the evolution of our crowd infectious diseases? One reason just mentioned is that agriculture sustains much higher human population densities than does the hunting-gathering lifestyle—on the average, 10 to 100 times higher. In addition, hunter-gatherers frequently shift camp and leave behind their own piles of feces with accumulated microbes and worm larvae. But farmers are sedentary and live amid their own sewage, thus providing microbes with a short path from one person's body into another's drinking water.

Some farming populations make it even easier for their own fecal bacteria and worms to infect new victims, by gathering their feces and urine and spreading them as fertilizer on the fields where people work. Irrigation agriculture and fish farming provide ideal living conditions for the snails carrying schistosomiasis and for flukes that burrow through our skin as we wade through the feces-laden water. Sedentary farmers become surrounded not only by their feces but also by disease transmitting rodents, attracted by the farmers' stored food. The forest clearings made by African farmers also provide ideal breeding habitats for malaria-transmitting mosquitoes.

If the rise of farming was thus a bonanza for our microbes, the rise of cities was a greater one, as still more densely packed human populations festered under even worse sanitation conditions. Not until the beginning of the 20th century did Europe's urban populations finally become self-sustaining: before then, constant immigration of healthy peasants from the countryside was necessary to make up for the constant deaths of city dwellers from crowd diseases. Another bonanza was the development of world trade routes, which by Roman times effectively joined the populations of Europe, Asia, and North Africa into one giant breeding ground for microbes. That's when smallpox finally reached Rome, as the Plague of Antoninus, which killed millions of Roman citizens between A.D. 165 and 180.

Similarly, bubonic plague first appeared in Europe as the Plague of Justinian (A.D. 542–43). But plague didn't begin to hit Europe with full force as the Black Death epidemics until A.D. 1346, when a new route for overland trade with China provided rapid transit, along Eurasia's east–west axis, for flea-infested furs from plague-ridden areas of Central Asia to Europe. Today, our jet planes have made even the longest intercontinental flights briefer than the duration of any human infectious disease. That's how an Aerolineas Argentinas airplane, stopping in Lima (Peru) in 1991, managed to deliver dozens of cholera-infected people that same day to my city of Los Angeles, over 3,000 miles from Lima. The explosive increase in world travel by Americans, and in immigration to the United States, is turning us into another melting pot—this time, of microbes that we previously dismissed as just causing exotic diseases in far-off countries.

THUS, WHEN THE human population became sufficiently large and concentrated, we reached the stage in our history at which we could at last evolve and sustain crowd diseases confined to our own species. But that conclusion presents a paradox: such diseases could never have existed before then! Instead, they had to evolve as new diseases. Where did those new diseases come from?

Evidence has recently been emerging from molecular studies of the disease-causing microbes themselves. For many of the microbes responsible for our unique diseases, molecular biologists can now identify the microbe's closest relatives. These also prove to be agents of crowd infectious diseases—but ones confined to various species of our domestic animals and pets! Among animals, too, epidemic diseases require large, dense populations and don't afflict just any animal: they're confined mainly to social animals providing the necessary large populations. Hence when we domesticated social animals, such as cows and pigs, they were already afflicted by epidemic diseases just waiting to be transferred to us.

For example, measles virus is most closely related to the virus causing rinderpest. That nasty epidemic disease affects cattle and many wild cud-chewing mammals, but not humans. Measles in turn doesn't afflict cattle. The close similarity of the measles virus to the rinderpest virus suggests that the latter transferred from cattle to humans and then evolved into the measles virus by changing its properties to adapt to us. That transfer is not at all surprising, considering that many peasant farmers live and sleep close to cows and their feces, urine, breath, sores, and blood. Our intimacy with cattle has been going on for the 9,000 years since we domesticated them—ample time for the rinderpest virus to discover us nearby. As Table 11.1 illustrates, others of our familiar infectious diseases can similarly be traced back to diseases of our animal friends.

GIVEN OUR PROXIMITY to the animals we love, we must be getting constantly bombarded by their microbes. Those invaders get winnowed by natural selection, and only a few of them succeed in establishing themselves as human diseases. A quick survey of current diseases lets us trace out four stages in the evolution of a specialized human disease from an animal precursor.

The first stage is illustrated by dozens of diseases that we now and then pick up directly from our pets and domestic animals. They include cat-scratch fever from our cats, leptospirosis from our dogs, psittacosis from our chickens and parrots, and brucellosis from our cattle. We're similarly liable to pick up diseases from wild animals, such as the tularemia that hunters can get from skinning wild rabbits. All those microbes are still at an early stage in their evolution into specialized human pathogens. They still don't get transmitted directly from one person to another, and even their transfer to us from animals remains uncommon.

In the second stage a former animal pathogen evolves to the point where it does get transmitted directly between people and causes epidemics.

TABLE 11.1 Deadly Gifts from Our Animal Friends

Human Disease	*Animal with Most Closely Related Pathogen*
Measles	cattle (rinderpest)
Tuberculosis	cattle
Smallpox	cattle (cowpox) or other livestock with related pox viruses
Flu	pigs and ducks
Pertussis	pigs, dogs
Falciparum malaria	birds (chickens and ducks?)